

Near Net shape Technologies
AlBeMet® NNSB and AlBeWeld™

14710 W. Portage River S. Road • Elmore, OH 43416 • (419) 862-4127 or (419) 862-4173

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Technology Days in the Government, September 17, 2003



Near Net Shape Technologies

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- **Near Net Shape HIP (Hot Isostatic Press)**
 - Recent History
 - In Development under MAI Contract F33615-99-2-5215
 - Currently producing selected Prototypes
 - Broad Commercial availability
 - September 2004
- **AlBeWeld™**
 - Spin-off from MAI Contract F33615-99-2-5216
 - In Development
 - Currently producing selected Prototypes and Orders
 - As reported properties
 - Parameters Optimized (.125" and Below)
 - Parameters in Investigation (.500" and Below)
 - Broad Commercial availability
 - March 2004

A More Disciplined Approach to NNSB using HIP AlBeMet®

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METALS AFFORDABILITY INITIATIVE (MAI) “Core” Program Cooperative Agreement F33615-99-2-5215

LiftFan Targeted for AlBeMet

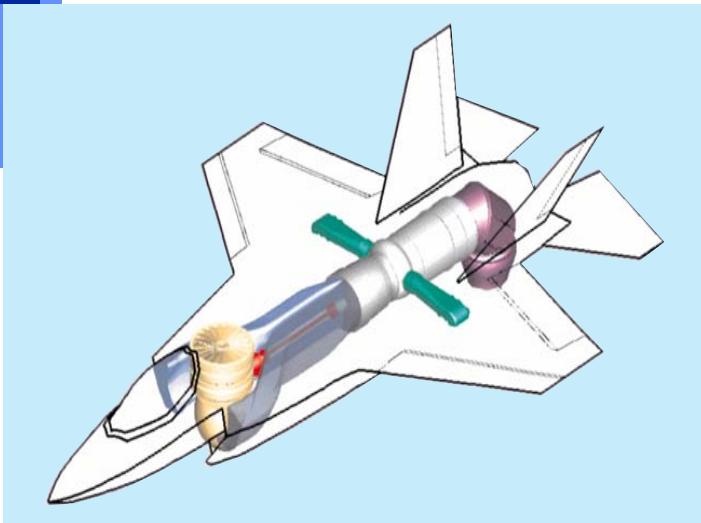
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- Joint Strike Fighter will be built in 3 versions.
- Version for Marines and British will be STOVL.



**Lockheed X-35B STOVL Demonstrator
Vertical Landing at Edwards AFB**

**The JSF aircraft will use a
shaft driven LiftFan that
converts 25,000 HP into
18,000 lb vertical thrust.**



HIP Shaped Blank

■ Experimental Plan

- Produce Constituent Data for Finite Element Modeling (FEM)
- HIP .67 Scale Intermediate Bearing Support to Establish Feasibility and Provide Iterative Step to Improve FEM Capability
- HIP Full Scale Intermediate Bearing Support to Validate FEM



HIP'ing complex cans designed by FEM will provide cost effective blanks for machining components

HIP Shaped Blank

- **Development & Optimization Plan**
 - **HIP Several Iterations of the Full Scale Intermediate Bearing Support to Optimize Blank Design for Cost Effectiveness**
 - **Establish Material Property Relationship Between Shaped Blank Component and Ride Along Can**



Development, optimization and material properties to be developed with outside funding.

Actual NNSB Part

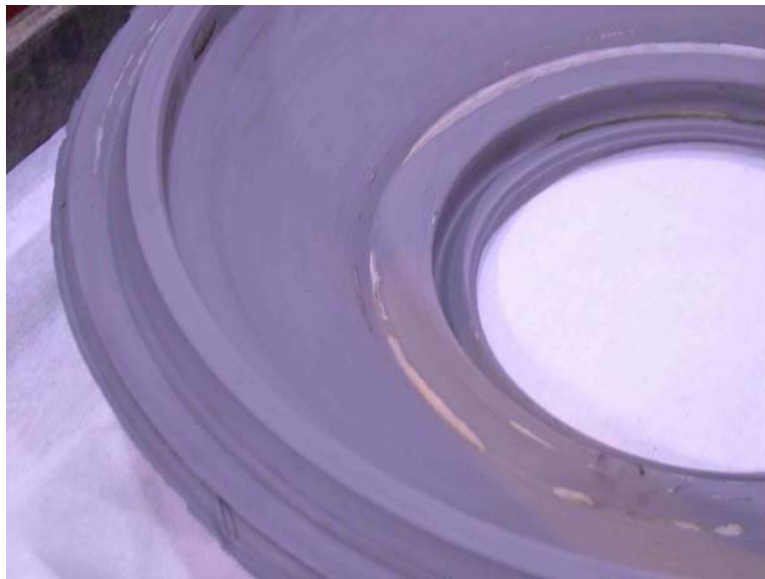
JSF Lift Fan 2/3 Scale Part

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Top View



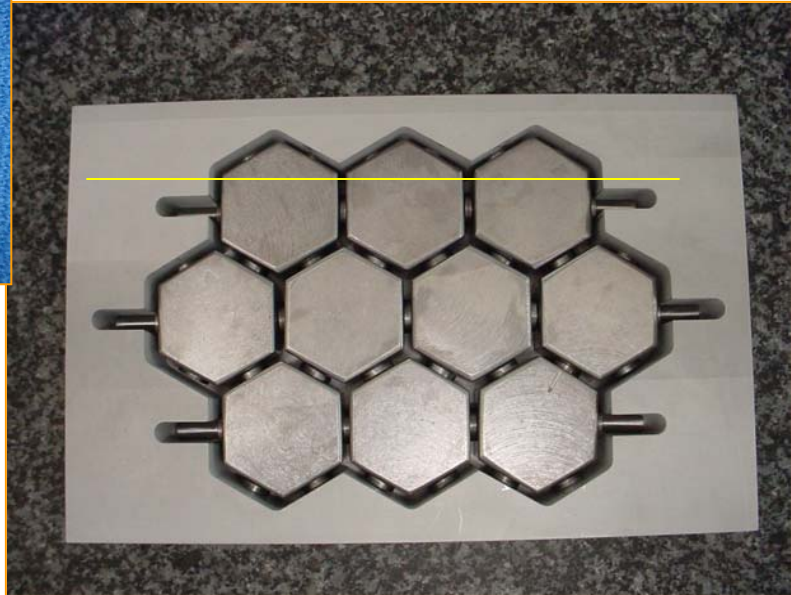
Bottom View



NNNSB (Near Net Shape Blanks) Recent History

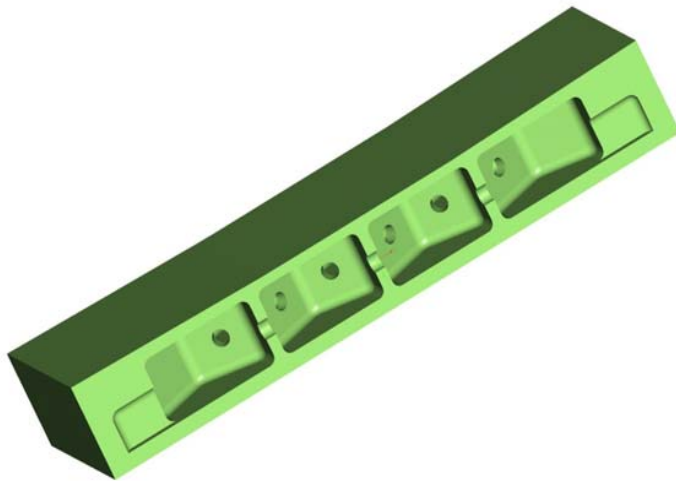
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- Honeycomb monolithic mirrors blanks



Monolithic Close Back Cell

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Detailed Experimental Plan

Intermediate Bearing Support

HIP'ed Blank & Machine Development

Design Review

- Rolls Royce provides drawing
- Brush Wellman reviews design with HIP can designer, Synertech
- Can specification written
 - Consolidation factor
 - HIP tolerances
 - Be-Al blank dimensions
- Synertech/Brush Wellman design and produce HIP can

Development

- Develop FEM HIP model
- Fabricate 2/3 Scale HIP can
- HIP consolidate prototype part
- Evaluate dimensions compared to Model
- **Adjust design to full scale can as needed**
- **Establish mechanical property relationship between ride along can, part & HIP'ed data base**
- **Optimize and validate process**

Product Evaluation

- **Blend chemistry**
- **Dimensional map**
- **Density test of part & ride along can**
- **Tensile test ride along can**
- **Remove the can mechanical or chemical machining**
- **Dye penetrant after Rough Machining**

EKV Drop-in Replacement using O-30 Beryllium

Cost Estimate

Price Comparison

EKV Sunshade NNSB

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- Price for material by current billet machined approach
 - Material Only
 - (15) PC Baseline 100%
- Price for material by NNSB (Initial ROM)
 - (15) pieces 60-65% of Baseline
 - NRE/Tooling \$27,500.
- Based on ROM fabrication costs a price equal to 70-75% of the baseline for this “Drop-in Replacement” is possible.
- Requires only a specification change from S-200F to O-30H.

AlBeMet®/Beryllium NNSB Summary

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- **Demonstrated the capability to model Near Net Shape Blanks**
 - **Use of external and internal mandrels**
 - **Both re-usable and expendable**
- **Open Back Net Shape, Lightweight Optical Mirror Blanks:**
 - **Scalable to the 1 meter size range**
 - **AlBeMet® or Beryllium Spherical Powder**
 - **Can be demonstrated in the near future**

AlBeMet® NNS Technologies using Wrought Alloys

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METALS AFFORDABILITY INITIATIVE (MAI) “Dust” Program Cooperative Agreement F33615-99-2-5216 E-Beam Welding Spin-off

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AlBeWeld™

Aluminum Beryllium E-Beam Welding

Why AlBeWeld™?

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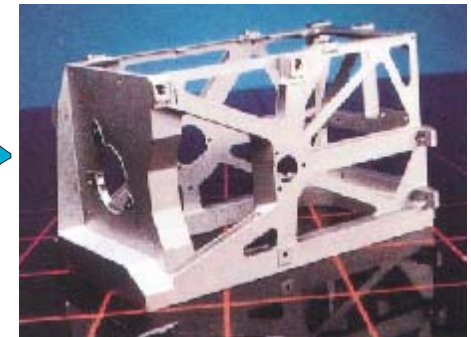
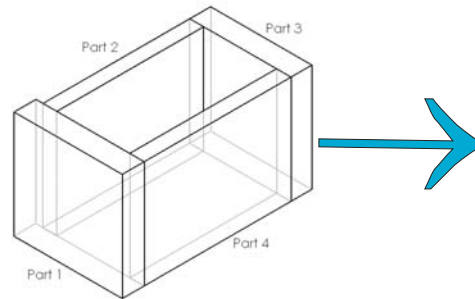
Goals of the Technology

- Achieve the material cost benefit of a “brazement” with the material properties of monolithic AlBeMet
- Combine Smaller pieces together to make parts larger than possible with current capabilities
- Incorporate machine features on smaller pieces with lower costs than on complex, larger blanks

AlBeMet® Solid Block 107.5 Lbs.
1 solid block 9.32” x 9.35” x 16.2

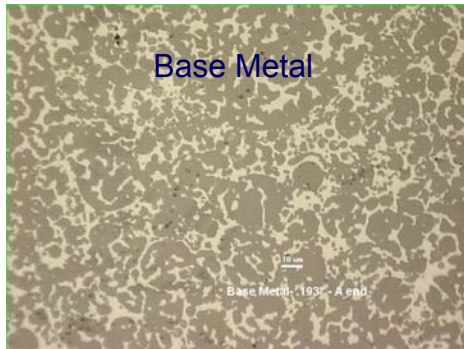
AlBeWeld Blank 45.8 Lbs.
Piece 1 - 1.80” x 9.87” x 9.32”
Piece 2 - 1.90” x 9.32” x 9.35”
Piece 3 - 1.20” x 9.32” x 12.70”
Piece 4 - 1.25” x 9.32” x 12.70”

Finished Part 10 Lbs.

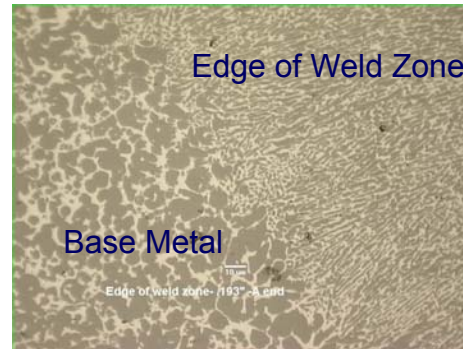


The Progression of a Weld Joint (.191" thick)

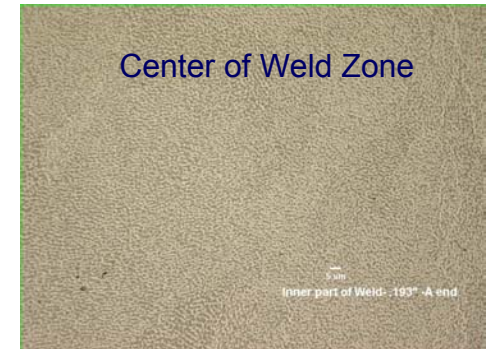
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Base metal is typical microstructure of AlBeMet 162



At the edge of the weld zone, microstructure is coarser than the center and finer than the base metal.



Center of weld zone is the finest microstructure in this specimen.

AlBeWeld™ Capabilities

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Internal

- **Hamilton Standard 52" EB Welder**
 - EB Welder controls are 2 axis
 - 7.5 KW Capability
- **Working space 36"(Y) x 23"(Z) x 52" (X)**
- **AM162 can be welded in thinner sections**

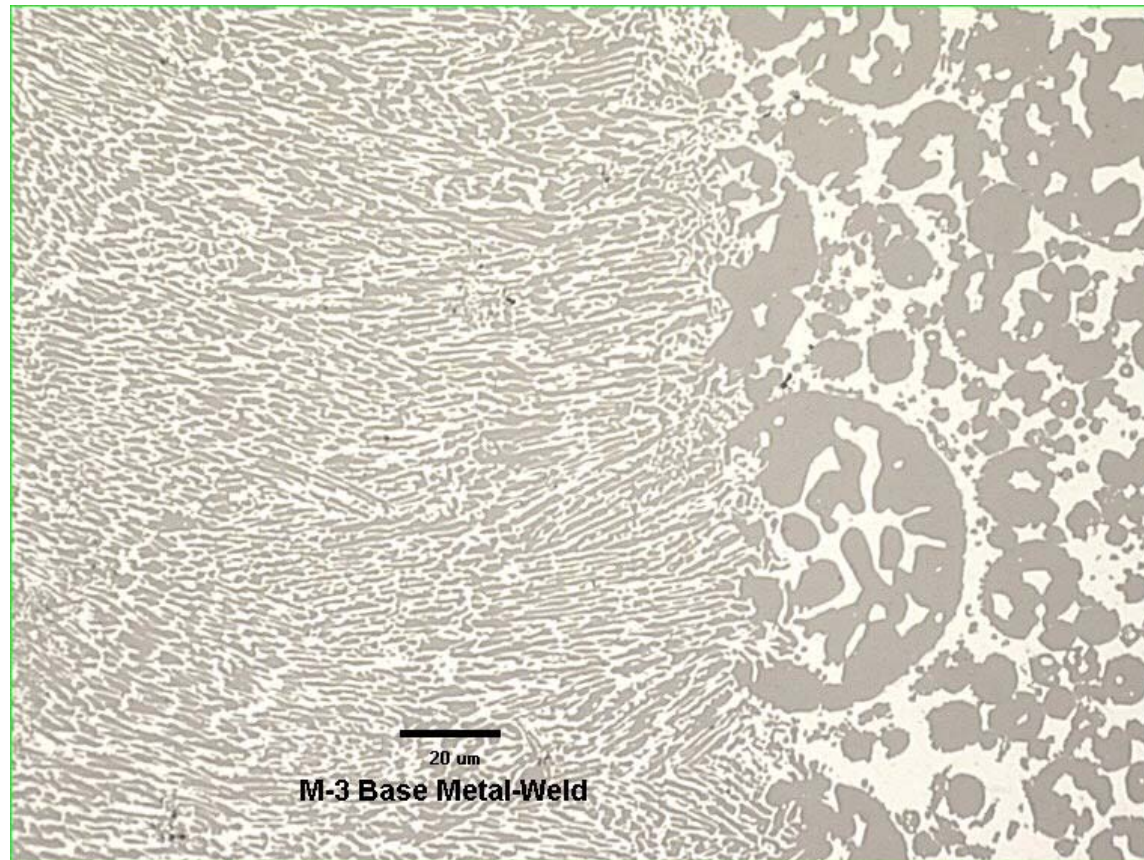
Partner

- **EB Welder can accommodate 54"(Y) x 40"(Z) x 108"(X)**
 - 25 KW capability
 - Larger Sizes Possible
- **EB Welder controls are 5 axis plus rotation**
- **We have welded material at .125" thick. Material up to 0.5" thick is expected to produce high quality welds.**

Weld Joint Interface

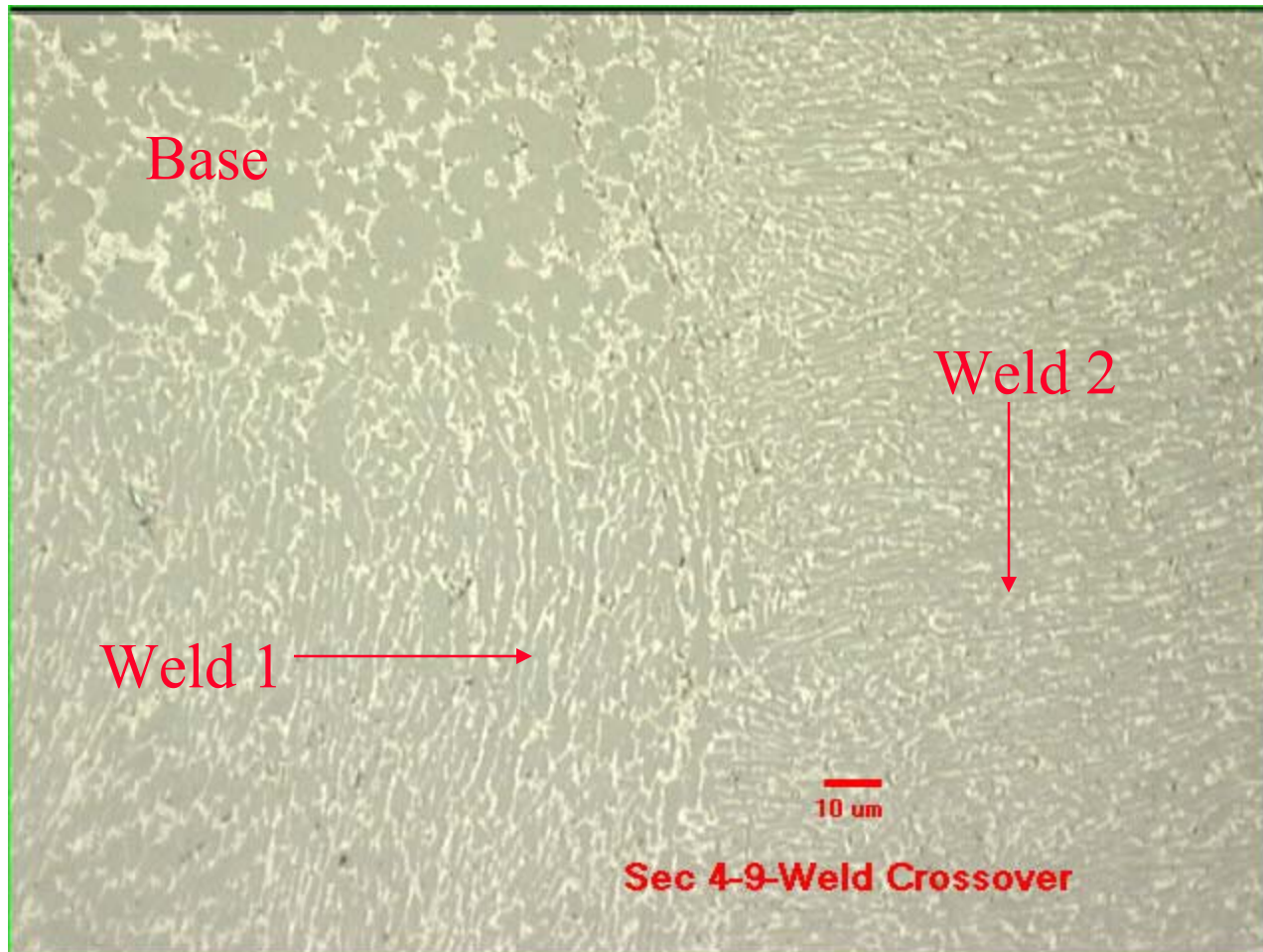
1/2" Thickness

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Double Weld Intersection

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AlBeWeld Prototype Development

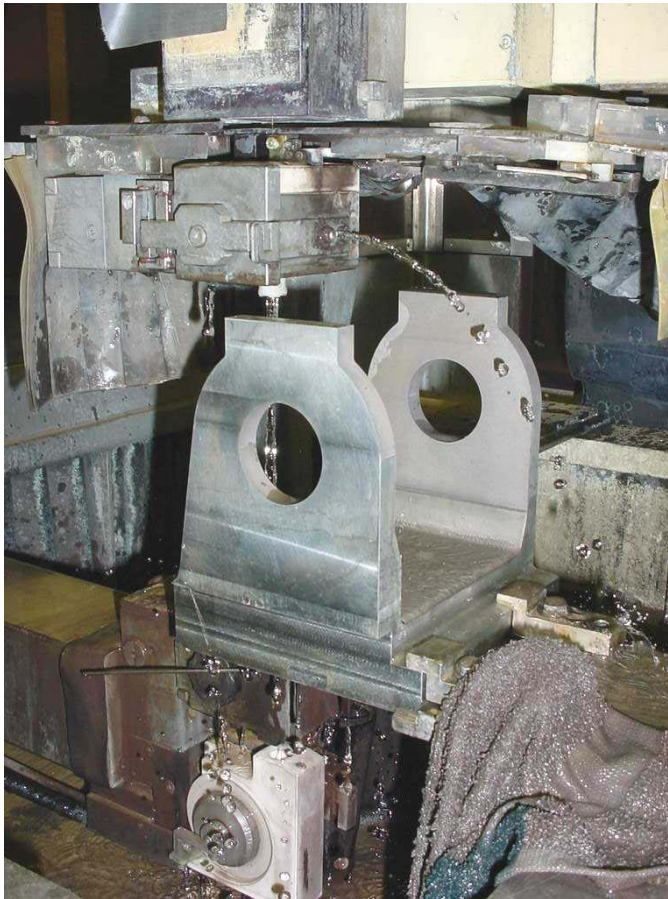
AlBeWeld Prototypes

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- **Gimbal Prototypes**
 - Two Concept Prototypes Complete.
 - We should expect to get an order for two Engineering Development Units.
- **Optical Barrel Repair**
- **ROM Estimate for the EKV Sunshade**

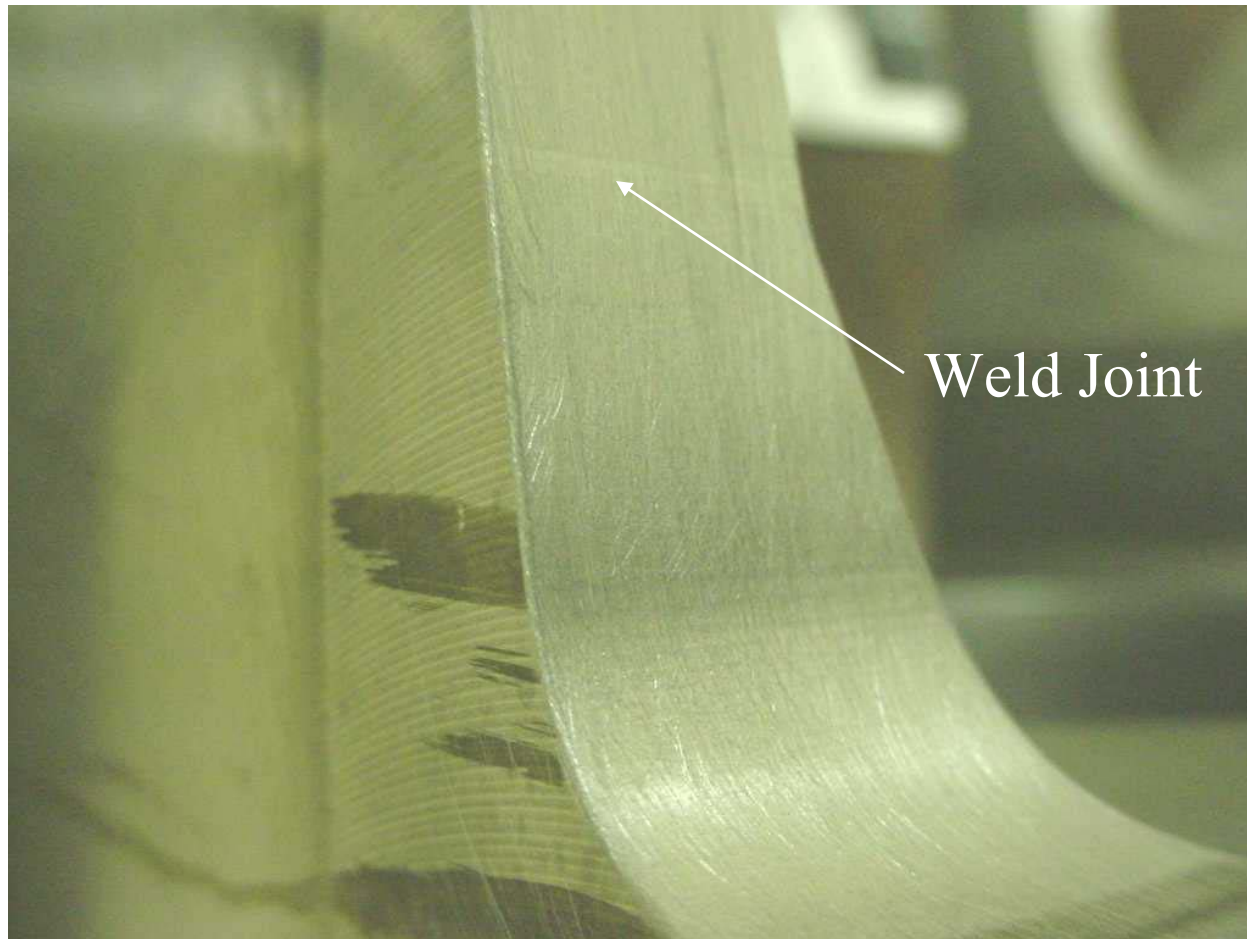
Gimbal Weld Blank Prototypes

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Gimbal Weld Joint - Post Machining

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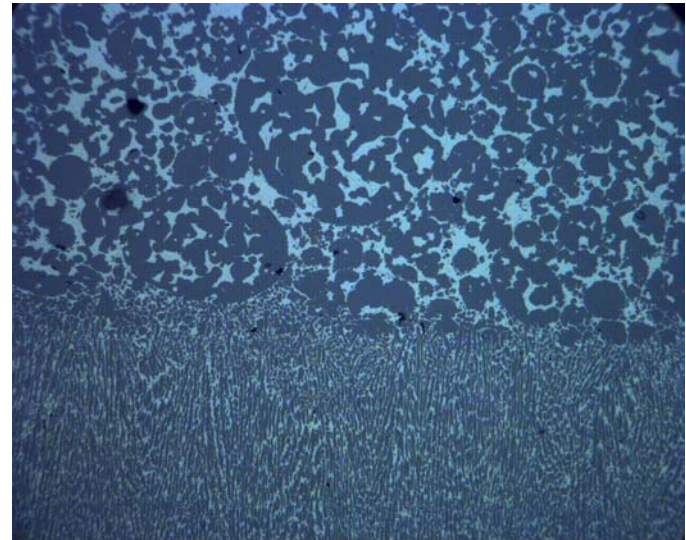
AM162HIP Weld Results

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Weld Tensile Results - HIP Block (Gimbal Prototype)

	UTS	YS	% Elongation
PM	45.9	34.8	4.7
PM	44.9	37.2	4.3
Cond			
A	46.1	33.5	3.9
A	43.3	33.9	2.5
Cond			
B	40.5	32.6	1.6
B	40.7	33.2	1.6

⁽¹⁾ Premature Break



Electron Beam Welded AM162HIP

400X - Thickness .400" sample

Specified Mechanical Properties of Aluminum-Beryllium AM162

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Material Type	Heat Treatment	Yield Strength MPa (KSI)	Ultimate Strength MPa (KSI)	Elongation %
HIP	593°C/24 hours	191 (28)	262 (38)	2
Typical	593°C/24 hours	(30-32)	(42-43)	4-5
Weld Strengths (as tested)	None	(32-33)	(40-46)	1.6-4.0
Extruded (L/T)	593°C/24 hours	276 (40)/276 (40)	279 (55)/330 (48)	7/2
Typical	593°C/24 hours	(45-48)/(45-48)	(60-65)/(55-58)	8-10/2-4
Weld Strengths (as tested)	None	Not tested	Not tested	Not tested
Sheet	593°C/24 hours	276 (40)	344 (50)	5
Typical	593°C/24 hours	(44-46)	(56-58)	5-7
Weld Strengths (as tested)	None	(42-44)	(50-52)	.8-1.8

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AlBeWeld Repair!!!!

Optical Barrel Repair Problem

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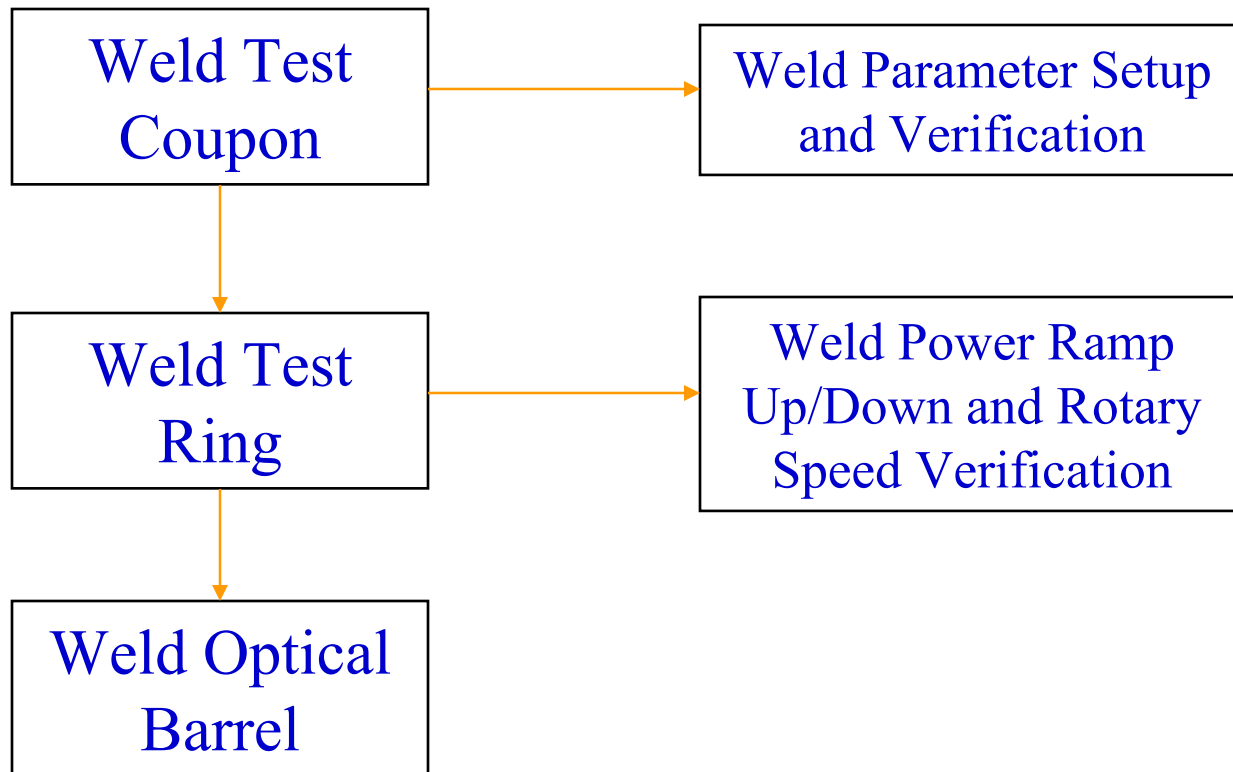
AlBeWeld Repair

- **Problem**
 - **Optical Barrel ID was Machined Oversized**
- **Solution**
 - **Remove oversized section and EB Weld a new repair ring to the top of the Optical Barrel.**

Optical Barrel Repair Process

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Welding Process



Optical Barrel Repair

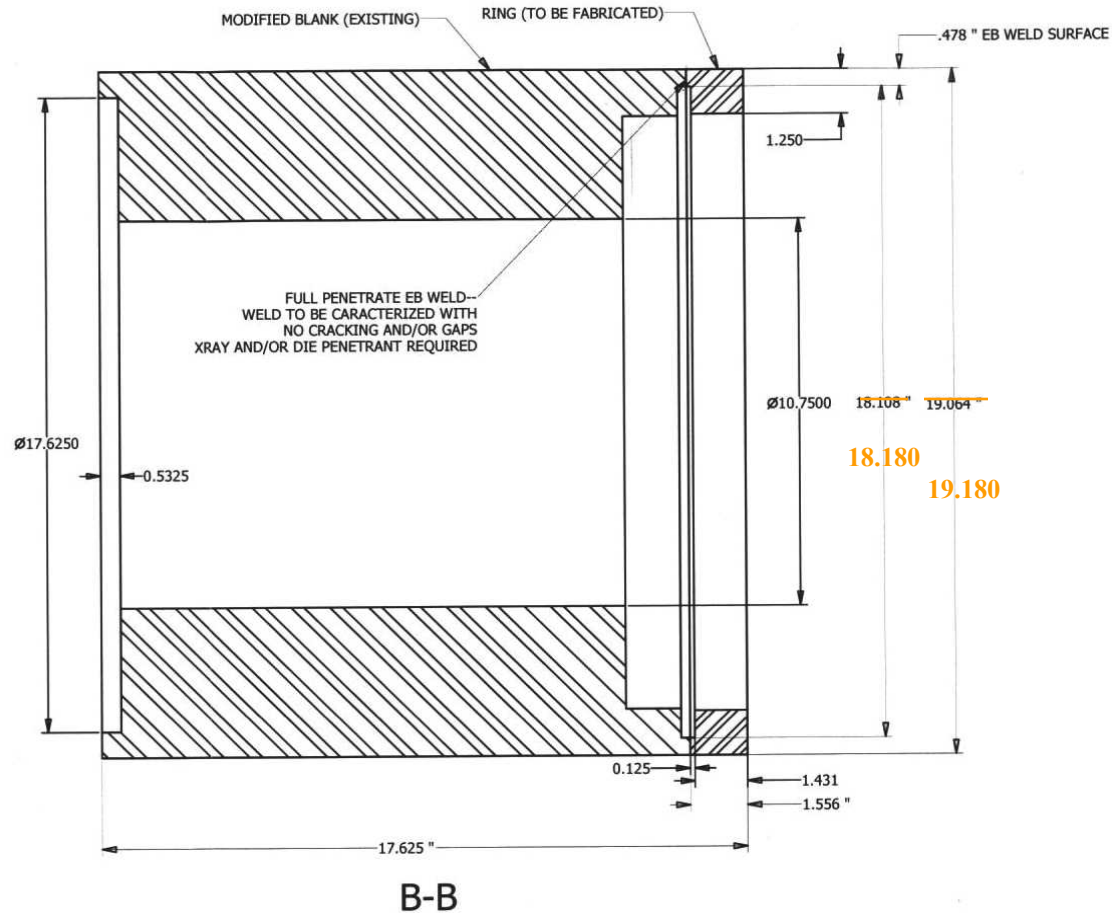
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12" Weld Test Coupon



Optical Barrel Repair

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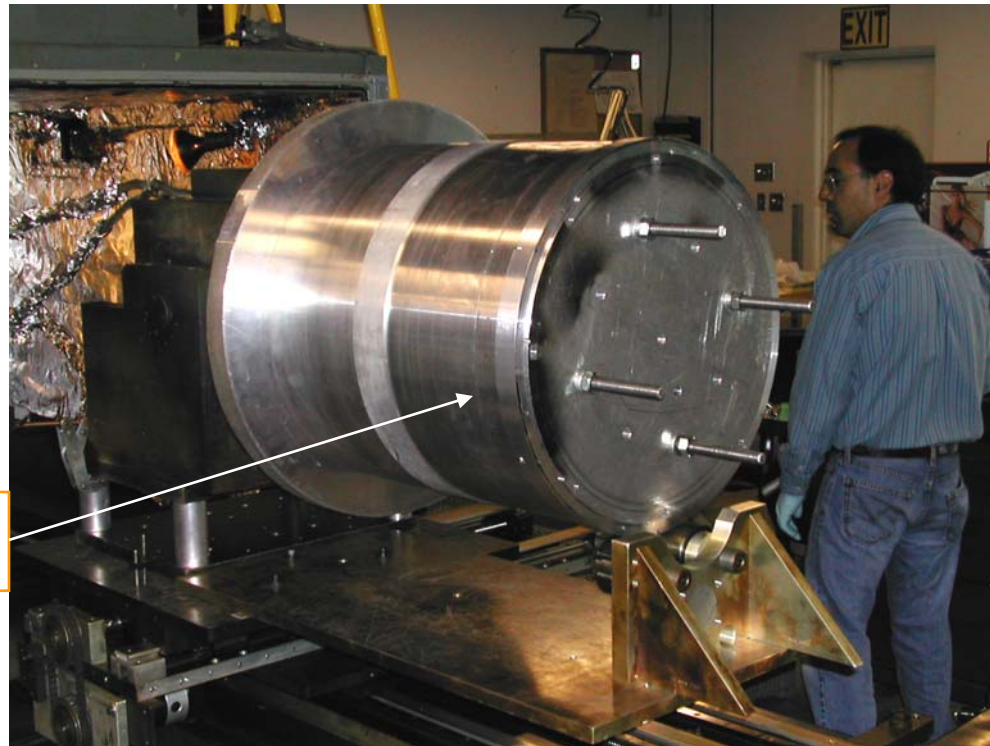


Optical Barrel Cross-Section View

Optical Barrel Repair

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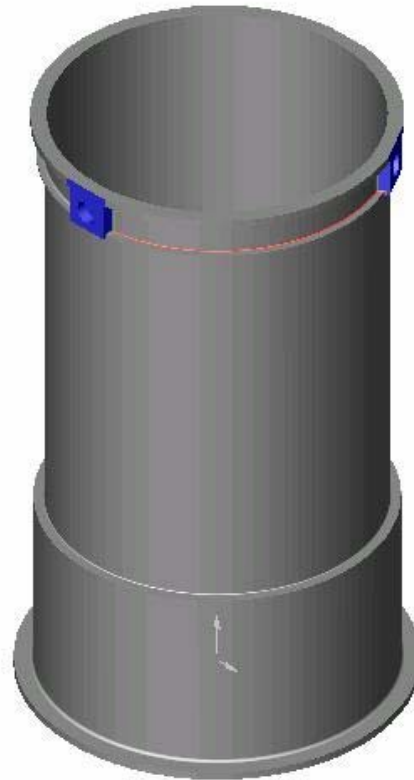
Optical Barrel and Fixture



Weld Joint

EKV Sunshade Fabrication Approach

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**2. Form
sheet into
tube, then
seam weld**

**1. Machined
Flanges from
Tube Stock**

**3. Assemble into
fixture, E-Beam
Weld, Finish
Machine, assemble,
coat**

Price Comparison

EKV Sunshade E-Beam Welded

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- Price for completed Sunshade by current billet machined approach
 - (15) PC Baseline 100%
- ROM Price for fabricated component (Initial ROM)
 - (15) PC Percent of Baseline 42.5-47.5%
 - NRE/Tooling \$17,500.
- Requires a specification change from S-200F to AM162 (70% Be/30% 1100 Aluminum by vol.) and a thinner wall (to match weight).

AlBeWeld™ Summary

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- E-Beam welding has been successfully demonstrated for:
 - Scale up from .100” Thickness to .500” Thickness
 - High strength (Close to Parent Metal)
 - 50-75% of the Parent Metal Ductility
 - Joining without filler metals
 - CTE compatible
 - Repair of expensive AlBeMet® structures

Next Steps

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- **Phase 1 Samples at .350" and .500"**
 - Welding complete
 - Visual results excellent
 - Properties and Metallurgical Evaluation in Progress
- **Phase 2**
 - DOE to optimize parameters with Properties
 - In development
 - Expected Start later this month
- **Prototypes**
 - Several applications in development/design
 - Already delivered acceptable parts up to .500" Thick